

M.5.3.8 Evolutionary Light Water Reactor

Studies of evaluation basis accidents and beyond evaluation basis accidents have been performed for an evolutionary LWR in the *Evolutionary/Advanced Light Water Reactor Data Report*. The studies postulated a set of accident scenarios that were representative of the risks and consequences for workers and the public that can be expected if the facility were constructed and operated. The advanced boiling reactor studies were selected as representative studies for the evolutionary LWRs.

M.5.3.8.1 Accident Scenarios and Source Terms

A wide range of hazardous conditions and potential accidents from operating the facility were identified as candidates to represent the risks to workers and the public. Through a screening process, four evaluation basis accidents and two beyond evaluation basis accidents were selected for further definition and analysis. Supporting information for these accidents has been documented in *Assessment of Radioactive Releases to the Environment Due to the Incorporation of Tritium Targets into an Advanced Light Water Reactor to Produce Tritium*, October 1995.

Evaluation Basis Accidents

Failure of Small Primary Coolant Line Outside of Containment

This accident postulated the rupture of an instrument line outside the drywell but inside the reactor building. It is not possible to isolate the leak. The flow from the instrument line is limited by a 0.64-centimeter (0.25-inch) diameter flow-restricting orifice inside the drywell. The total integrated mass of fluid released into the reactor building is 5,442 kg (12,000 pounds [lb]), with approximately 2,270 kg (5,000 lb) flashed into steam. The accident sequence is terminated by the orderly shutdown and depressurization of the reactor. Table M.5.3.8.1-1 presents the source term released to the environment. The analysis did not estimate the accident annual frequency of occurrence. It is expected that the postulated annual frequency of occurrence would range from 0.01/yr to 1.0×10^{-4} /yr. For the purpose of calculating the point estimate of risk for the postulated accident, the accident annual frequency of occurrence is assumed to be 1.0×10^{-3} /yr.

Steam System Piping Break Outside Containment

This accident postulated a large steam line break outside of containment downstream of the outermost isolation valve. The plant is designed to immediately detect the break and initiate isolation of the broken line. Table M.5.3.8.1-1 presents the source term released to the environment. The analysis did not estimate the accident annual frequency of occurrence. It is expected that the postulated annual frequency of occurrence would range from 1.0×10^{-4} /yr to 1.0×10^{-6} /yr. For the purpose of calculating the point estimate of risk for the postulated accident, the accident annual frequency of occurrence is assumed to be 1.0×10^{-5} /yr.

Cleanup Water Line Break Outside Containment

This accident postulated a large cleanup water line break outside of containment. The analysis assumed that the non-filtered inventory in both the regenerative and non-regenerative heat exchangers is released through the break. The leak is automatically isolated approximately 75 seconds after the break. Table M.5.3.8.1-1 presents the source term released to the environment. The analysis did not estimate the accident annual frequency of occurrence. It is expected that the postulated annual frequency of occurrence would range from 1.0×10^{-4} /yr to 1.0×10^{-6} /yr. For the purpose of calculating the point estimate of risk for the postulated accident, the accident annual frequency of occurrence is assumed to be 1.0×10^{-5} /yr.

Table M.5.3.8.1-1. Advanced Boiling Water Reactor Evaluation Basis Accident Source Terms

Accident Parameter	Accident Scenario			
	Failure of Small Primary Coolant Line Outside Containment	Steam System Piping Break Outside Containment	Cleanup Water Line Break Outside Containment	Fuel Handling
Frequency of occurrence ^a	1.0×10^{-3}	1.0×10^{-5}	1.0×10^{-5}	1.0×10^{-5}
Isotope Released to Environment (Ci)				
I-131	4.2	43	2.4	130
I-132	34	410	5.5	160
I-133	25	260	5.9	120
I-134	49	720	8.3	6.0×10^{-6}
I-135	36	390	6.8	21
Xe-131m	0	2.9×10^{-4}	0	84
Xe-133m	0	5.5×10^{-3}	0	1.1×10^3
Xe-133	0	0.14	0	2.7×10^4
Xe-135m	0	0.47	0	220
Xe-135	0	1.3	0	1.9×10^4
Xe-137	0	2.0	0	2.1×10^{-10}
Xe-138	0	1.5	0	4.3×10^{-10}
Xe-139	0	0.70	0	0
Kr-83m	0	0.040	0	3.8
Kr-85m	0	0.078	0	55
Kr-85	0	1.9×10^{-4}	0	250
Kr-87	0	0.24	0	7.1×10^{-3}
Kr-88	0	0.23	0	14
Kr-89	0	1.6	0	8.1×10^{-11}
Kr-90	0	0.42	0	0

^a Midpoint of the estimated frequency range.

Source: GE nda.

Fuel Handling Accident

This accident postulated a spent fuel assembly dropped into the reactor core. The analysis assumed that some rods in the dropped assembly and in the struck assembly fail. Table M.5.3.8.1-1 presents the source term released to the environment. The analysis did not estimate the accident annual frequency of occurrence. It is expected that the postulated annual frequency of occurrence would range from $1.0 \times 10^{-4}/\text{yr}$ to $1.0 \times 10^{-6}/\text{yr}$. For the purpose of calculating the point estimate of risk for the postulated accident, the accident annual frequency of occurrence is assumed to be $1.0 \times 10^{-5}/\text{yr}$.

Beyond Evaluation Basis Accidents

Chapter 19 of the *Advanced Boiling Water Reactor Standard Safety Analysis Report* evaluated beyond design basis accidents that were initiated by either internal events (for example, a sequence of equipment failures) or external events (for example, severe natural phenomena such as beyond design basis earthquakes). The evaluation of external event-initiated accidents did not present accident frequency data, release fractions, or source term data that could be used to analyze the accident consequences and risks for this class of accident in this document.

Numerous internal event-initiated accidents were evaluated in Chapter 19 of the Advanced Boiling Water Reactor (BWR) Standard SAR. The accidents that had a common source term were grouped together and evaluated as a single accident, and a single total annual frequency of occurrence was defined for the group. Release fractions and the annual frequency of occurrence were defined for two accidents. The annual frequency of occurrence for the ten accidents in Chapter 19 of the Advanced BWR Standard SAR ranged from $7.0 \times 10^{-8}/\text{yr}$ to less than $1.0 \times 10^{-10}/\text{yr}$. Two of the ten accidents had an annual frequency of occurrence greater than $1.0 \times 10^{-8}/\text{yr}$. These two accidents were selected for evaluation.

Anticipated Transient Without Scram and Loss of Core Cooling

The postulated accident is an anticipated transient without scram with the loss of core cooling. Due to the loss of core cooling, core damage results, the vessel fails in approximately 1 hour, and the containment fails in approximately 19 hours. The source term is presented in Table M.5.3.8.1–2. The annual frequency of occurrence for this accident is $1.3 \times 10^{-7}/\text{yr}$.

Large Break Loss of Coolant Accident and Loss of Core Cooling

The postulated accident is represented by a source term that is common for a group of accidents. The group of accidents includes the following:

- Loss of all core cooling, vessel failure at high pressure, firewater addition system switched to drywell spray mode, containment overpressure protection system rupture disk ruptures, and release negligible—less than 0.1 percent volatile fission products.
- Loss of all core cooling, vessel failure at high pressure, passive flooder and drywell spray available, containment overpressure protection system rupture disk ruptures, and release negligible—less than 0.1 percent volatile fission products.
- Large break loss of coolant accident, loss of all core cooling, firewater addition system switched to drywell spray mode, containment overpressure protection system rupture disk ruptures, and release negligible—less than 0.1 percent volatile fission products.
- Station blackout with reactor core isolation cooling operating for 8 hours, offsite power restored at 8 hours, firewater addition system switched to drywell spray mode, containment overpressure protection system rupture disk ruptures, and release negligible—less than 0.1 percent volatile fission products.
- Loss of all core cooling, vessel failure at low pressure, passive flooder available, containment overpressure protection system rupture disk ruptures, and release negligible—less than 0.1 percent volatile fission products.
- Loss of all core cooling, vessel failure at low pressure, firewater addition system switched to drywell spray mode, containment overpressure protection system rupture disk ruptures, and release negligible—less than 0.1 percent volatile fission products.

The source term is presented in Table M.5.3.8.1–2. The annual frequency of occurrence for the group of accidents is $2.1 \times 10^{-8}/\text{yr}$.

Table M.5.3.8.1-2. Advanced Boiling Water Reactor Beyond Evaluation Basis Accident Source Terms

Accident Parameter	Accident Scenario	
	Anticipated Transient Without Scram and Loss of Core Cooling	Large Break Loss of Coolant Accident and Loss of Core Cooling ^a
Frequency of occurrence ^b	1.3×10^{-7}	2.1×10^{-8}
Isotope Released to Environment (Ci)		
Kr-85	2.3×10^6	5.2×10^5
Kr-85m	1.0×10^6	2.3×10^7
Kr-87	1.7×10^6	3.9×10^7
Kr-88	2.3×10^6	5.2×10^7
Rb-86	0.53	0.30
I-131	2.6×10^3	18
I-132	3.8×10^3	25
I-133	4.8×10^3	31
I-134	5.3×10^3	35
I-135	4.7×10^3	31
Xe-133	9.1×10^6	2.1×10^8
Xe-135	6.7×10^6	1.5×10^8
Cs-134	200	110
Cs-136	150	86
Cs-137	210	120

^a Representative accident description for a group of accidents with the same source term.

^b Total frequency for a group of accidents with same source term.

Source: Source term derived from accident release fractions (GE nda) and core inventory (TTI 1995b).

M.5.3.8.2 Accident Impacts

The estimated impacts of the postulated accidents at each site are provided in Tables M.5.3.8.2-1 through M.5.3.8.2-6. The dose and cancer fatality estimates are based on the analysis of the accident source terms in Tables M.5.3.8.1-1 and M.5.3.8.1-2 using the MACCS computer code. [Text deleted.]

Table M.5.3.8.2-1. Evolutionary Light Water Reactor Accident Impacts at Hanford Site

Accident Scenario	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km		
	Dose (rem)	Probability of Latent Cancer/ Prompt Fatality ^a	Dose (rem)	Probability of Latent Cancer/ Prompt Fatality ^a	Dose (person·rem)	Cancer/Prompt Fatalities ^b	
Failure of small primary coolant line outside containment	5.6x10 ⁻³	2.2x10 ⁻⁶ /0	5.6x10 ⁻⁴	2.8x10 ⁻⁷ /0	0.10	5.2x10 ⁻⁵ /0	1.0x10 ⁻³
Scram system piping break outside containment	0.061	2.5x10 ⁻⁵ /0	6.2x10 ⁻³	3.1x10 ⁻⁶ /0	1.11	5.5x10 ⁻⁴ /0	1.0x10 ⁻⁵
Cleanup water line break outside containment	1.7x10 ⁻³	6.7x10 ⁻⁷ /0	1.7x10 ⁻⁴	8.4x10 ⁻⁸ /0	0.036	1.8x10 ⁻⁵ /0	1.0x10 ⁻⁵
Fuel handling	0.071	2.8x10 ⁻⁵ /0	8.6x10 ⁻³	4.3x10 ⁻⁶ /0	2.0	1.0x10 ⁻³ /0	1.0x10 ⁻⁵
Anticipated transient with scram and loss of core cooling	40.4	0.021/0	5.4	2.7x10 ⁻³ /0	1,650	0.82/0	1.3x10 ⁻⁷
Large break loss of coolant accident and loss of core cooling	422	0.089/0.40	85.6	0.08/9.7x10 ⁻³	11,700	5.9/0	2.1x10 ⁻⁸
[Text deleted.]							

^a Increase likelihood (or probability) of cancer or prompt fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

^b Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

Note: All values are mean values. Advanced BWR data was used as surrogate data for the evolutionary LWR.
Source: Calculated using the source terms in Tables M.5.3.8.1-1 and M.5.3.8.1-2 and the MACCS computer code.

Table M.5.3.8.2-2. Evolutionary Light Water Reactor Accident Impacts at Nevada Test Site

Accident Scenario	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Dose (rem)	Probability of Latent Cancer/ Prompt Fatality ^a (rem)	Dose (rem)	Probability of Latent Cancer/ Prompt Fatality ^a (rem)	Dose (person-rem)	Cancer/Prompt Fatalities ^b (per year)
Failure of small primary coolant line outside containment	3.9x10 ⁻³	1.5x10 ⁻⁶ / 0	8.3x10 ⁻⁵	4.1x10 ⁻⁸ 0	3.2x10 ⁻³	1.6x10 ⁻⁶ / 0
Scram system piping break outside containment	0.043	1.7x10 ⁻⁵ / 0	9.0x10 ⁻⁴	4.5x10 ⁻⁷ / 0	0.033	1.7x10 ⁻⁵ / 0
Cleanup water line break outside containment	1.2x10 ⁻³	4.7x10 ⁻⁷ / 0	2.5x10 ⁻⁵	1.2x10 ⁻⁸ / 0	1.1x10 ⁻³	5.6x10 ⁻⁷ / 0
Fuel handling	0.048	1.9x10 ⁻⁵ / 0	1.5x10 ⁻³	7.6x10 ⁻⁷ / 0	0.051	2.6x10 ⁻⁵ / 0
Anticipated transient with scram and loss of core cooling	27	0.014/ 0	1.0	5.0x10 ⁻⁴ / 0	50.9	0.026/ 0
Large break loss of coolant accident and loss of core cooling	279	0.087/ 0.25	17.8	0.15/ 2.4x10 ⁻⁴	118	0.059/ 0
[Text deleted.]						

^a Increase likelihood (or probability) of cancer or prompt fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

^b Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

Note: All values are mean values. Advanced BWR data was used as surrogate data for the evolutionary LWR.

Source: Calculated using the source terms in Tables M.5.3.8.1-1 and M.5.3.8.1-2 and the MACCS computer code.

Table M.5.3.8.2-3. Evolutionary Light Water Reactor Accident Impacts at Idaho National Engineering Laboratory

Accident Scenario	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Dose (rem)	Probability of Latent Cancer/ Prompt Fatality ^a (rem)	Dose (rem)	Probability of Latent Cancer/ Prompt Fatality ^a (person-rem)	Dose (person-rem)	Number of Latent Cancer/ Prompt Fatalities ^b
Failure of small primary coolant line outside containment	5.5x10 ⁻³	2.2x10 ⁻⁶ / 0	5.0x10 ⁻⁵	2.5x10 ⁻⁸ / 0	0.043	2.2x10 ⁻⁵ / 0
Scram system piping break outside containment	0.061	2.4x10 ⁻⁵ / 0	5.4x10 ⁻⁴	2.7x10 ⁻⁷ / 0	0.45	2.3x10 ⁻⁴ / 0
Cleanup water line break outside containment	1.6x10 ⁻³	6.6x10 ⁻⁷ / 0	1.5x10 ⁻⁵	7.6x10 ⁻⁹ / 0	0.015	7.6x10 ⁻⁶ / 0
Fuel handling	0.068	2.7x10 ⁻⁵ / 0	1.0x10 ⁻³	5.1x10 ⁻⁷ / 0	0.65	3.3x10 ⁻⁴ / 0
Anticipated transient with scram and loss of core cooling	36.3	0.020/ 0	0.66	3.3x10 ⁻⁴ / 0	689	0.35/ 0
Large break loss of coolant accident and loss of core cooling	385	0.071/ 0.36	12.4	0.010/ 0	1,150	0.57/ 0
[Text deleted.]						

^a Increase likelihood (or probability) of cancer or prompt fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

^b Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

Note: All values are mean values. Advanced BWR data was used as surrogate data for the evolutionary LWR.

Source: Calculated using the source terms in Tables M.5.3.8.1-1 and M.5.3.8.1-2 and the MACCS computer code.

Table M.5.3.8.2-4. Evolutionary Light Water Reactor Accident Impacts at Pantex Plant

Accident Scenario	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Dose (rem)	Probability of Latent Cancer/ Prompt Fatality ^a	Dose (rem)	Probability of Latent Cancer/ Prompt Fatality ^a	Dose (person-rem)	Number of Latent Cancer/Prompt Fatalities ^b (per year)
Failure of small primary coolant line outside containment	2.2x10 ⁻³	8.8x10 ⁻⁷ /0	1.6x10 ⁻³	7.9x10 ⁻⁷ /0	0.063	3.2x10 ⁻⁵ /0
Scram system piping break outside containment	0.024	9.7x10 ⁻⁶ /0	0.017	8.7x10 ⁻⁶ /0	0.68	3.4x10 ⁻⁴ /0
Cleanup water line break outside containment	6.5x10 ⁻⁴	2.6x10 ⁻⁷ /0	4.7x10 ⁻⁴	2.3x10 ⁻⁷ /0	0.021	1.1x10 ⁻⁵ /0
Fuel handling	0.027	1.1x10 ⁻⁵ /0	0.020	9.9x10 ⁻⁶ /0	0.97	4.9x10 ⁻⁴ /0
Anticipated transient with scram and loss of core cooling	16.4	7.2x10 ⁻³ /0	12.0	6.5x10 ⁻³ /0	813	0.41/0
Large break loss of coolant accident and loss of core cooling	162	0.095/0.080	129	0.10/0.047	4,660	2.3/0
[Text deleted.]						

^a Increase likelihood (or probability) of cancer or prompt fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

^b Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

Note: All values are mean values. Advanced BWR data was used as surrogate data for the evolutionary LWR.
Source: Calculated using the source terms in Tables M.5.3.8.1-1 and M.5.3.8.1-2 and the MACCS computer code.

Table M.5.3.8.2-5. Evolutionary Light Water Reactor Accident Impacts at Oak Ridge Reservation

Accident Scenario	Worker at 665 m		Maximum Offsite Individual		Population to 80 km		
	Dose (rem)	Probability of Latent Cancer/ Prompt Fatality ^a	Dose (rem)	Probability of Latent Cancer/ Prompt Fatality ^a	Dose (person·rem)	Cancer/Prompt Fatalities ^b	Number of Latent Accident Frequency (per year)
Failure of small primary coolant line outside containment	6.9×10^{-3}	$2.8 \times 10^{-6}/$	6.9×10^{-3}	$3.5 \times 10^{-6}/$	0.43	$2.2 \times 10^{-4}/$	1.0×10^{-3}
Scram system piping break outside containment	0.076	$3.0 \times 10^{-5}/$	0.076	$3.8 \times 10^{-5}/$	4.6	$2.3 \times 10^{-3}/$	1.0×10^{-5}
Cleanup water line break outside containment	2.1×10^{-3}	$8.3 \times 10^{-7}/$	2.1×10^{-3}	$1.0 \times 10^{-6}/$	0.15	$7.4 \times 10^{-5}/$	1.0×10^{-5}
Fuel handling	0.085	$3.4 \times 10^{-5}/$	0.085	$4.3 \times 10^{-5}/$	7.8	$3.9 \times 10^{-3}/$	1.0×10^{-5}
Anticipated transient with scram and loss of core cooling	50.6	$0.028/$	50.6	$0.035/$	6,250	$3.1/$	1.3×10^{-7}
Large break loss of coolant accident and loss of core cooling	474	$0.058/$	474	$0.072/$	45,100	$22.2/$	2.1×10^{-8}
[Text deleted.]	0.56	0.56	0.56	0	0	0	

^a Increase likelihood (or probability) of cancer or prompt fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary [665 m for this facility at ORR], whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

^b Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

Note: All values are mean values. Advanced BWR data was used as surrogate data for the evolutionary LWR.

Source: Calculated using the source terms in Tables M.5.3.8.1-1 and M.5.3.8.1-2 and the MACCS computer code.

Table M.5.3.8.2-6. Evolutionary Light Water Reactor Accident Impacts at Savannah River Site

Accident Scenario	Worker at 1,000 m		Maximum Offsite Individual		Population to 80 km	
	Dose (rem)	Probability of Latent Cancer/ Prompt Fatality ^a	Dose (rem)	Probability of Latent Cancer/ Prompt Fatality ^a	Dose (person-rem)	Cancer/Prompt Fatalities ^b
Failure of small primary coolant line outside containment	3.5x10 ⁻³	1.4x10 ⁻⁶ / 0	4.2x10 ⁻⁵	2.1x10 ⁻⁸ / 0	0.15	7.5x10 ⁻⁵ / 0
Scram system piping break outside containment	0.039	1.6x10 ⁻⁵ / 0	4.5x10 ⁻⁴	2.3x10 ⁻⁷ / 0	1.6	7.9x10 ⁻⁴ / 0
Cleanup water line break outside containment	1.1x10 ⁻³	4.2x10 ⁻⁷ / 0	1.3x10 ⁻⁵	6.3x10 ⁻⁹ / 0	0.053	2.6x10 ⁻⁵ / 0
Fuel handling	0.045	1.8x10 ⁻⁵ / 0	7.7x10 ⁻⁴	3.9x10 ⁻⁷ / 0	2.5	1.3x10 ⁻³ / 0
Anticipated transient with scram and loss of core cooling	27.2	0.013/ 0	0.52	2.6x10 ⁻⁴ / 0	2,260	1.1/ 0
Large break loss of coolant accident and loss of core cooling	279	0.095/ 0.21	8.4	4.9x10 ⁻³ / 0	8,640	4.3/ 0
[Text deleted.]						

^a Increase likelihood (or probability) of cancer or prompt fatality to a hypothetical individual (a single onsite worker at a distance of 1,000 m or the site boundary, whichever is smaller, or to a hypothetical individual in the offsite population located at the site boundary) if exposed to the indicated dose. The value assumes the accident has occurred.

^b Estimated number of cancer fatalities in the entire offsite population out to a distance of 80 km if exposed to the indicated dose. The value assumes the accident has occurred.

Note: All values are mean values. Advanced BWR data was used as surrogate data for the evolutionary LWR.

Source: Calculated using the source terms in Tables M.5.3.8.1-1 and M.5.3.8.1-2 and the MACCS computer code.